Science and Technology Facilities Council

RAL Space

SLSTR A& B Lunar Calibration Status

D.L. Smith, M. Etxaluze

10th December 2021

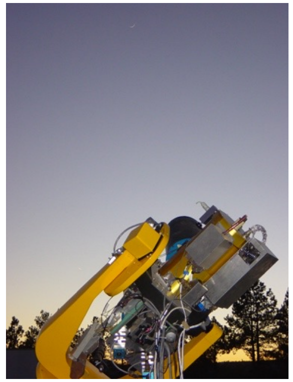
This work was funded by the EU under the Copernicus Program

European Commission

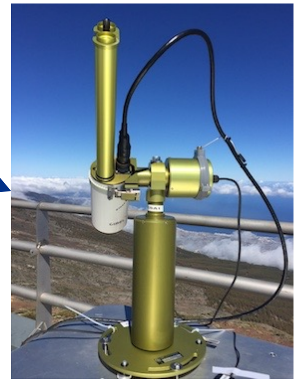
Copernicus

Lunar Irradiance Calibration

- Many satellite instruments used for earth observation are using Lunar observations to provide a calibration reference for the VIS-SWIR range.
- This is facilitated by accurate Lunar irradiance models derived from ground based radiometric observations of the moon.
- ROLO (RObotic Lunar Observatory) – USGS Field Station, Flagstaff Az (Tom Stone)
  - GIRO is the GSICS implementation of ROLO
  - Thomas C. Stone, "Radiometric Calibration Stability and Inter-calibration of Solar-band Instruments in Orbit Using the Moon,"Proc. SPIE 7081 70810X-1-8 (2008)



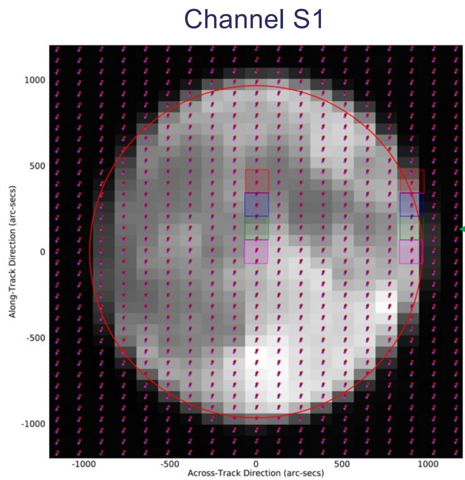
- LIME (Lunar Irradiance Model ESA) – Derived from measurements performed at Pico Teide in Tenerife (Spain)
  - Led by NPL (UK) in collaboration with the University of Valladolid (Spain) and the Flemish Institute for Technological Research (VITO) (Belgium).
  - http://calvalportal.ceos.org/lime



- Models provide integrated at sensor Lunar Irradiance spectra corrected for Lunar phase angle and distance to Sun and Spacecraft.

SLSTR Lunar Observations

- Observations of the moon by Sentinel-3 were performed after a roll manoeuvre with the satellite in a stable orientation.
  - S3B SLSTR observation was made on 27/07/2018 at ~5:20 UTC
  - S3A SLSTR observation was made on 04/07/2020 at ~16:10 UTC
  - Very similar lunar phase : -6.46deg (S3B) vs -6.29deg (S3A)
- SLSTR observed the Moon in nadir view with all the channels: the VIS (S1-S3), the SWIR (S4-S6) and the TIR (S7-S9).
- The manoeuvres also allowed observations of the cold sky to verify the dark signals of the VIS-SWIR channels and provide an additional low-temperature calibration point using the channels S8 and S9.



SLSTR L0 quick-look generated from the orbit containing the lunar observation. The image shows the view from spacecraft as it rotated away from, then back towards the Earth.

Science and Technology Facilities Council
RAL Space

Moon – 04-07-2020 – S3A

Time	Saturday, July 04, 2020, 16:00 UT
Phase	99.7% (13d 9h 19m)
Diameter	1900.4 arcseconds
Distance	377139 km (29.60 Earth diameters)
J2000 Right Ascension, Declination	18h 26m 49s, -23° 57' 44"
Subsolar Longitude, Latitude	11.368°, 0.425°
Sub-Earth Longitude, Latitude	4.653°, 0.916°
Position Angle	355.822°

https://svs.gsfc.nasa.gov/

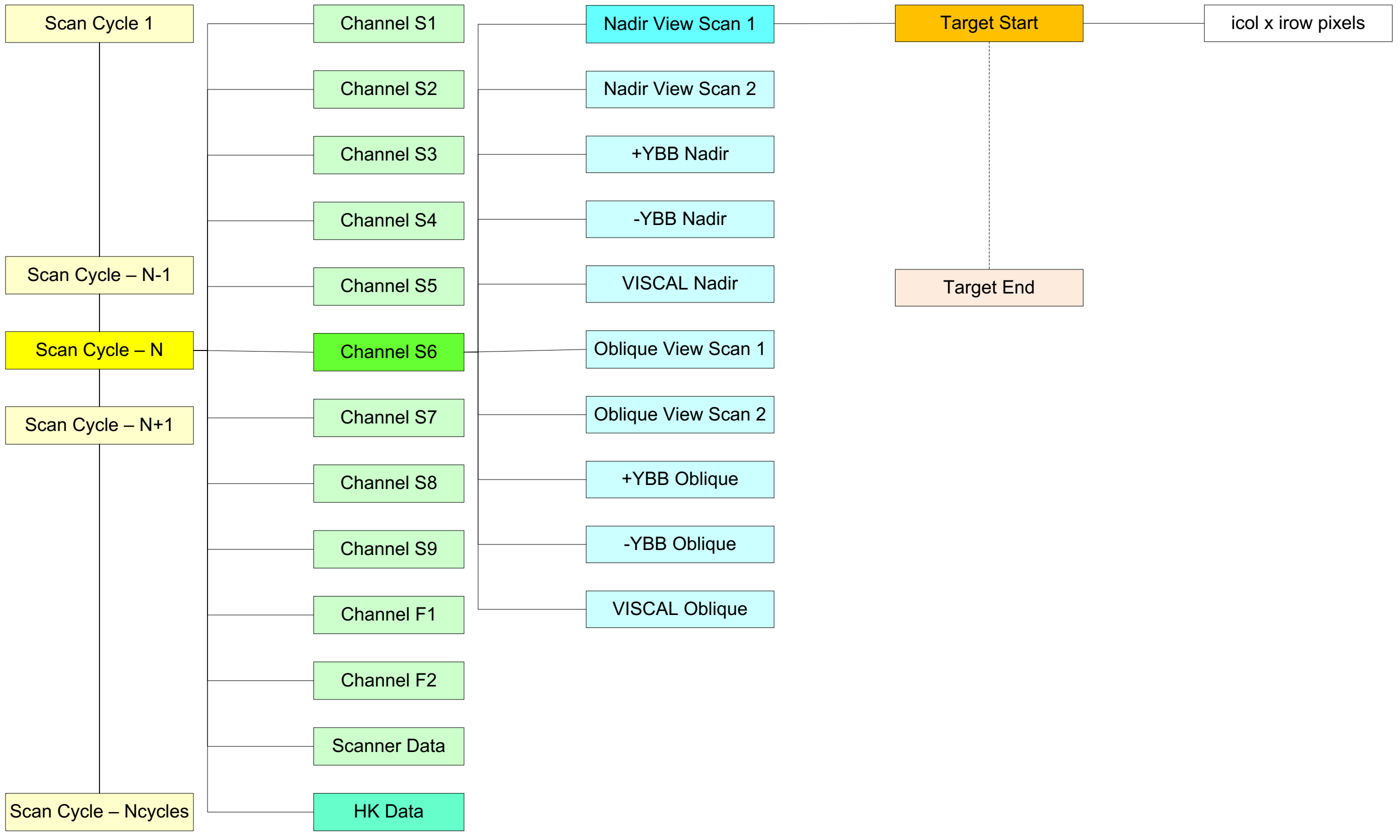
Moon – 27-07-2018 – S3B

Time	Friday, July 27, 2018, 05:00 UT
Phase	99.6% (14d 2h 12m)
Diameter	1764.3 arcseconds
Distance	406228 km (31.88 Earth diameters)
J2000 Right Ascension, Declination	19h 55m 19s, -19° 58' 43"
Subsolar Longitude, Latitude	7.324°, -0.051°
Sub-Earth Longitude, Latitude	0.438°, -1.037°
Position Angle	347.398

https://svs.gsfc.nasa.gov/

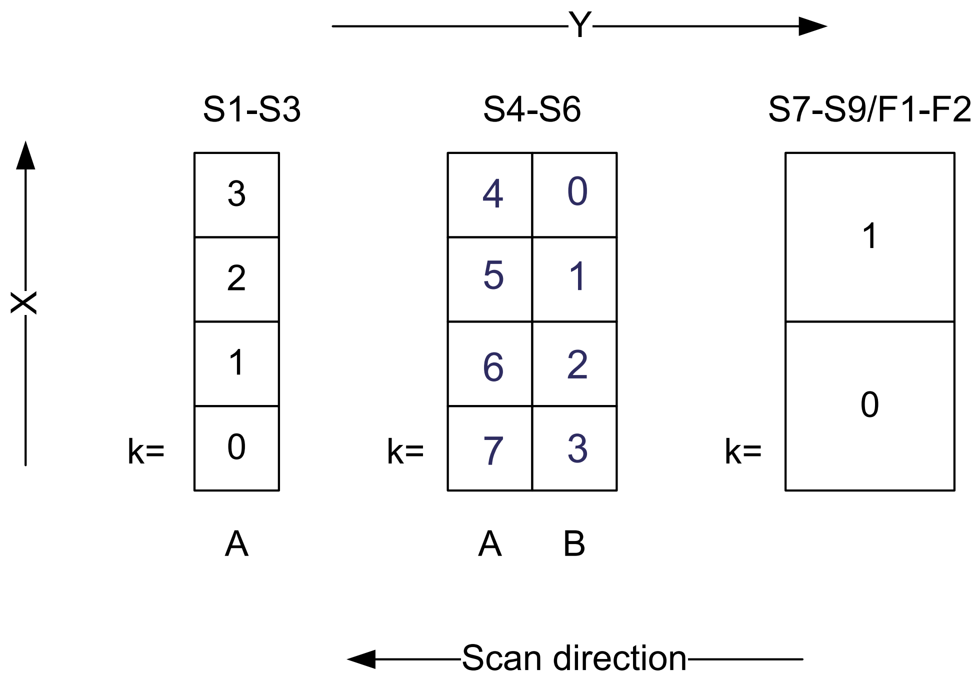
SLSTR L0 Data Structure

- For each scan cycle, L0 data contains packets for each channel and each view.
- Each view packet contains each detector counts for each pixel in the view.



Detector Ordering

- Note detectors read-out order is not conveniently in their optical position.
- E.g. In L0 data, SWIR detector corresponding to VIS detector 0 is read out last.
- We need to swap the order of the SWIR detectors so that they are aligned to the VIS channels.



RAL Space

Science and Technology Facilities Council

Conversion to Radiances

- From L0 packets we extract the nadir view detector counts for each channel
  - We get a matrix `L0_Counts`, of dimensions – `ndets, npixels, nscans`

- Apply non-linearity correction using L1 auxiliary files
  - `L0_Counts_corrected = L0_Counts/(NL+1)`

- Convert to reflectance using BB counts and Cal-Slope in VISCAL auxiliary file
  - `Reflectance = (L0_counts_corrected - BB_counts)*Cal_Slope`

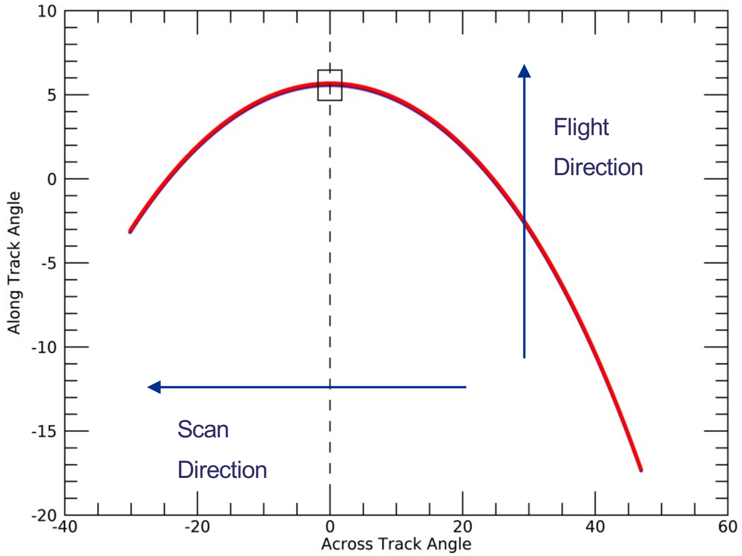
- Convert to radiance using Solar Irradiance in VISCAL auxiliary file
  - `Radiance = Reflectance*Solar_Irradiance/pi`

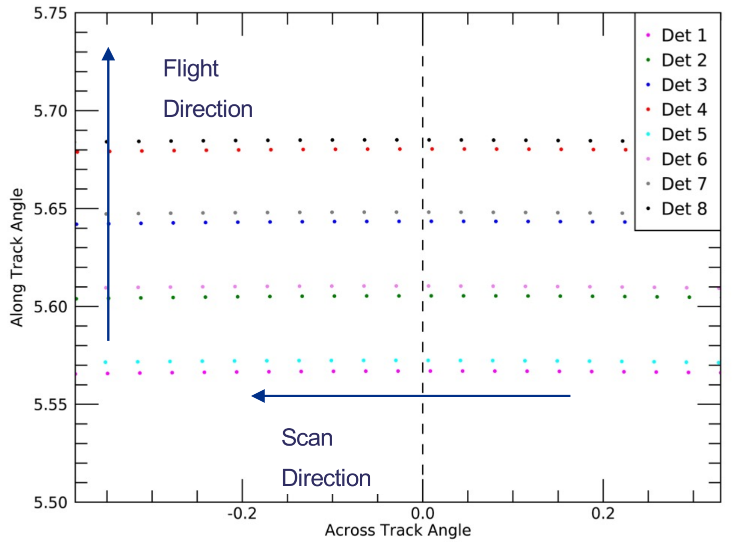
Geometric Calibration

- To map the moon pixels to the sky we need to consider the conical scanning geometry of the instrument.
- Pixel line-of-sight is determined using the instrument geometric model described in the L1 ATBD.

$$M_{ab}^{v} M'^{v}_{los_{grid}} = M_{ab}^{v} M_{ac}^{-1} M_{cm}^{v-1} \begin{pmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{pmatrix} M_{cm}^{v} M_{ac} M_{los_{grid}}^{v}$$

- However, the Moon is present only in the centre of the scan so occupies only a view pixels where the direction of the scan is only across-track.
- Hence only spacing between pixels is necessary. Absolute position is not critical.





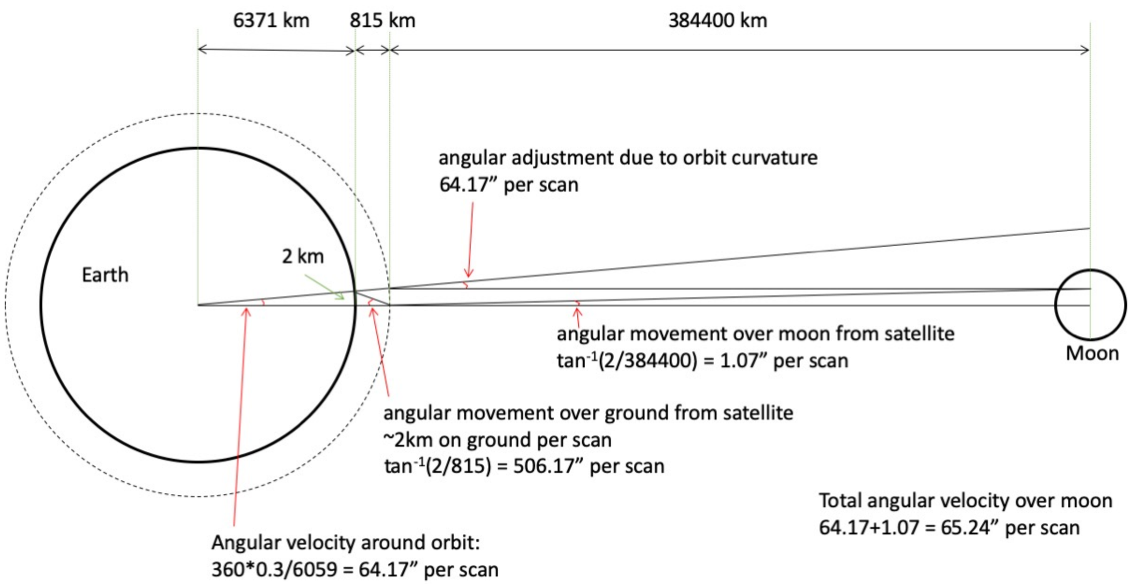
Science and Technology Facilities Council

RAL Space

Pixel Spacing

- Across track distance between pixels is determined by scan geometry and time between pixel samples (40us).
  - Across track interval on moon = 127.742” (For S1-S6)

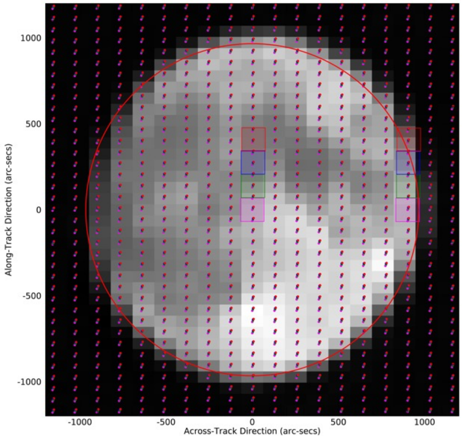
- Along track distance is determined by motion of satellite + scan interval
  - Along track interval on moon = 65.25”



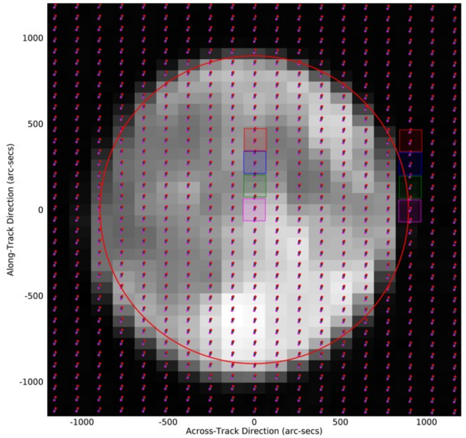
RAL Space

Lunar Mapping

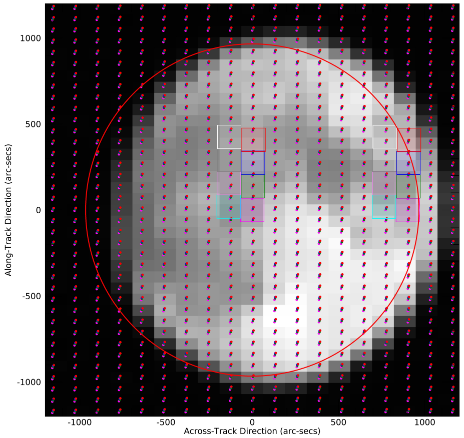
S3A – Channel S1



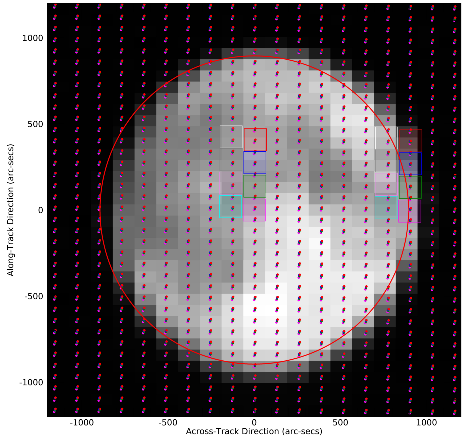
S3B – Channel S1



S3A – Channel S6



S3B – Channel S6



Points show relative position of detector centres based on LoS measurements & LoS model.

Squares show effective area of detector footprint projected onto sky.

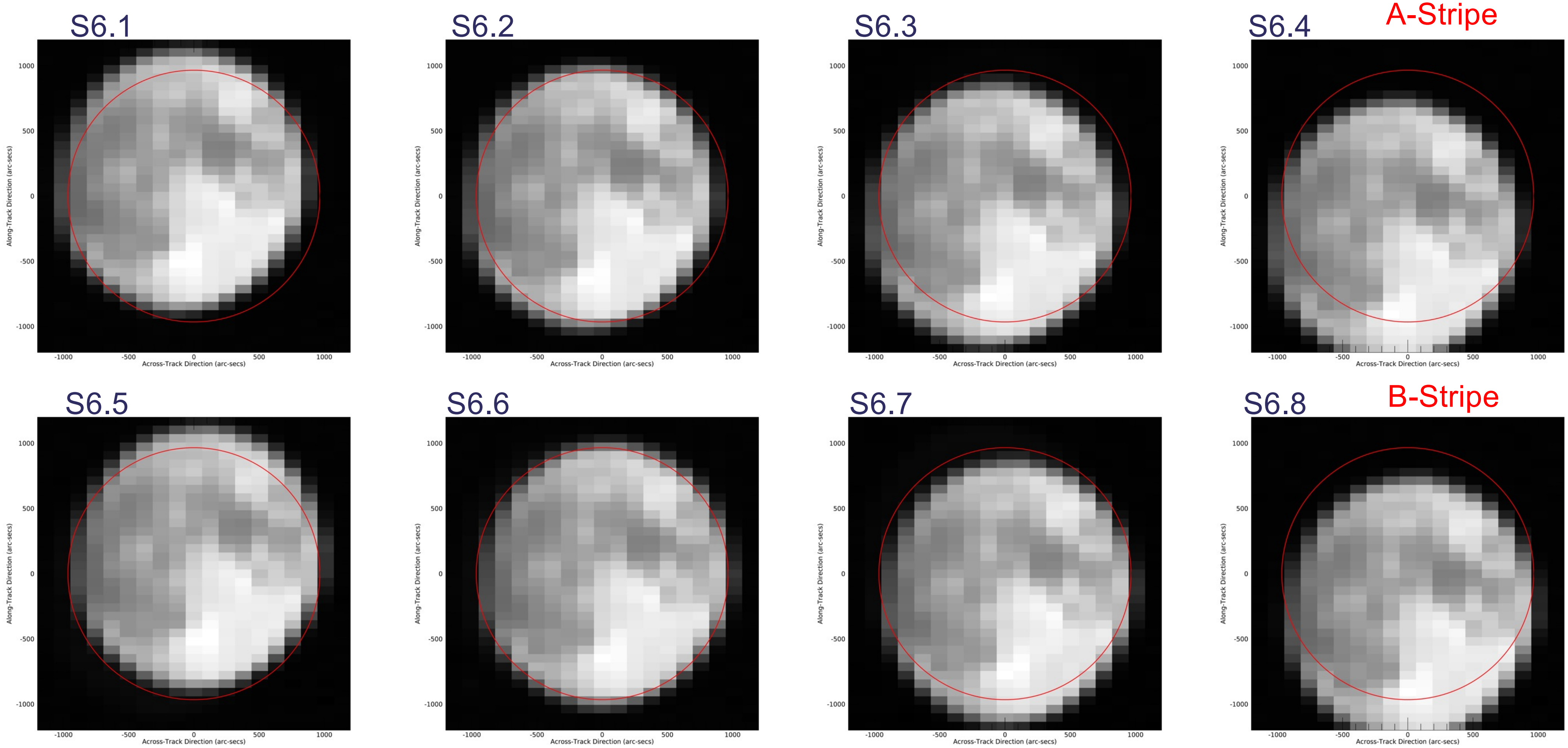
Circle shows size of moon disc as viewed from spacecraft.

Note S3B lunar image is smaller than S3A – due to differences in distance from satellite to moon.

Note also difference in moon across-track position between S6 and S1 detectors

RAL Space

Moon in Different Detectors – SLSTR-A Channel S6



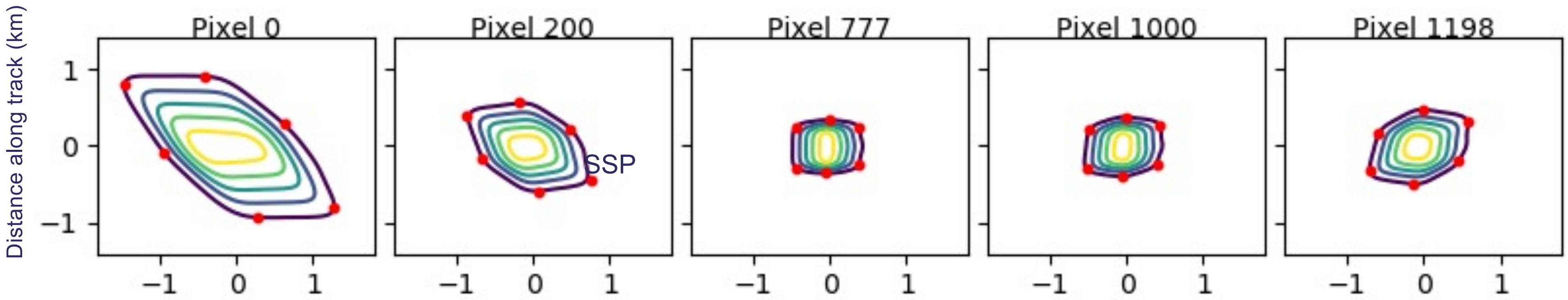
RAL Space

Note – Position of moon is different for each detector

Field of View + Scan

(Channel S6)

Nadir Pixels - as projected on Earth



Actual field of view in scan direction is defined by IFOV + Integration time (35 us)

The solid angle ($\omega[sr]$) is derived from the ground measurements taking into account the motion of the scanning mirror, the start time and integration time for each channel, and the movement of the satellite along track.

For lunar calibration centre pixel is used – movement is across track only

Science and
Technology
Facilities Council

RAL Space

Deriving Lunar Irradiances from SLSTR

- Standard GSICS approach (See Wu et al). No resampling is performed but the total integrated irradiance is computed using:

  $I_{moon} = \sum L_i \omega_{det} / f_{over}$

  L_i= Radiance measured in pixel i

  f_{over}= Oversampling Factor

  ω_{det}= Solid angle of detector which is constant so

  $I_{moon} = \omega_{det} \sum L_i / f_{over}$

- The oversampling factor is determined by

  f_{over} = FOV_ac_width/ac_interval∗FOV_al_width/al_interval

  = ω_{det}/(ac_interval*al_interval)

So

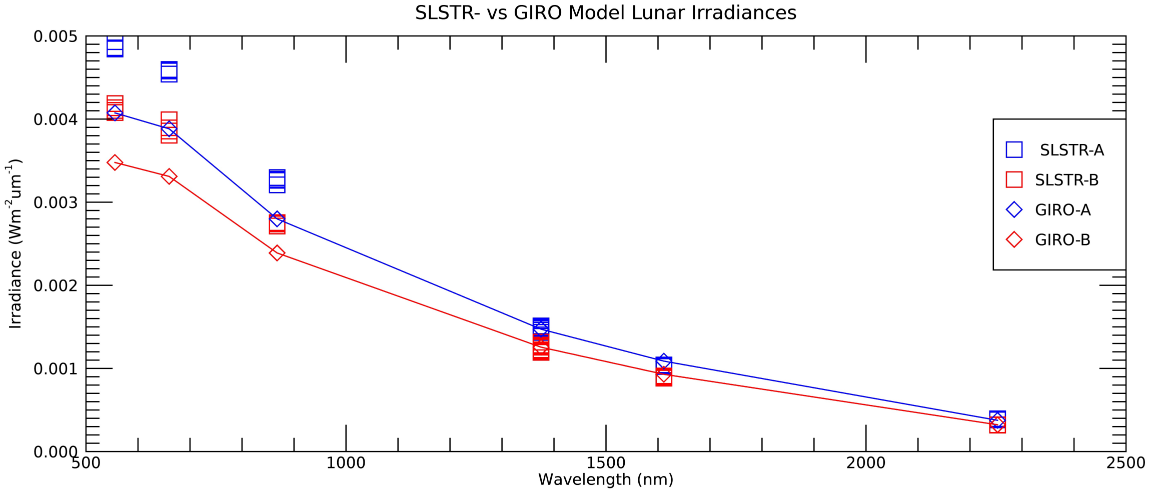
I_{moon} = ac_interval∗al_interval $\sum L_i$

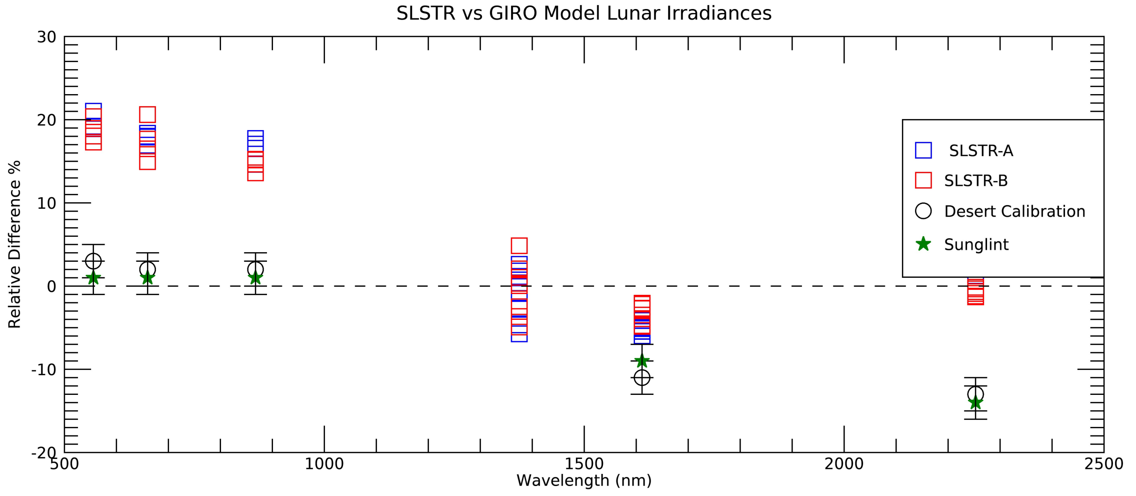
So the pixel solid-angle is **NOT** needed to derive irradiance since it cancels. What does matter is the pixel sampling interval.

Science and Technology Facilities Council

RAL Space

SLSTR vs GIRO





SLSTR-A and B irradiances are consistent with each other.

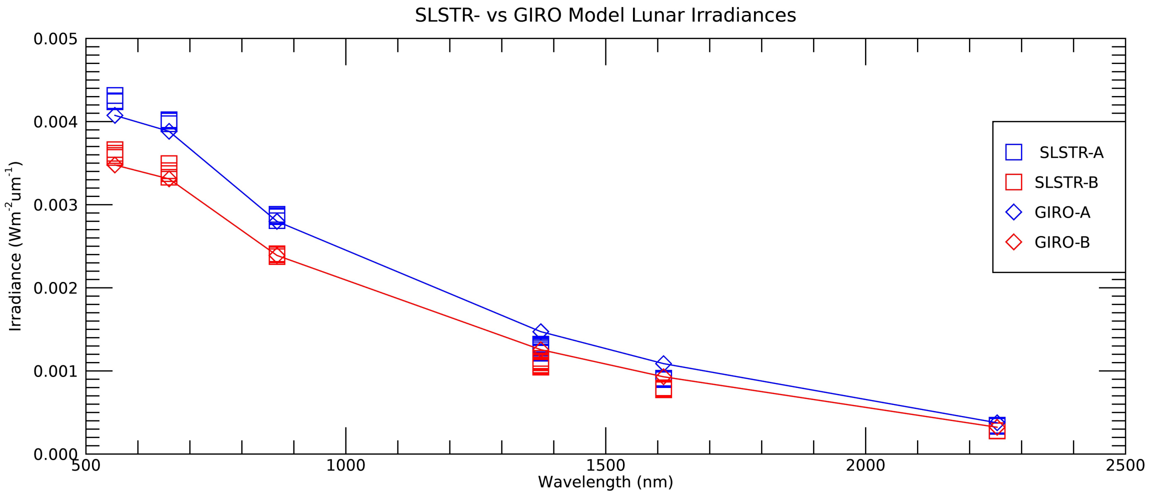
I.e. S3B irradiances ~ 0.85*S3A irradiances

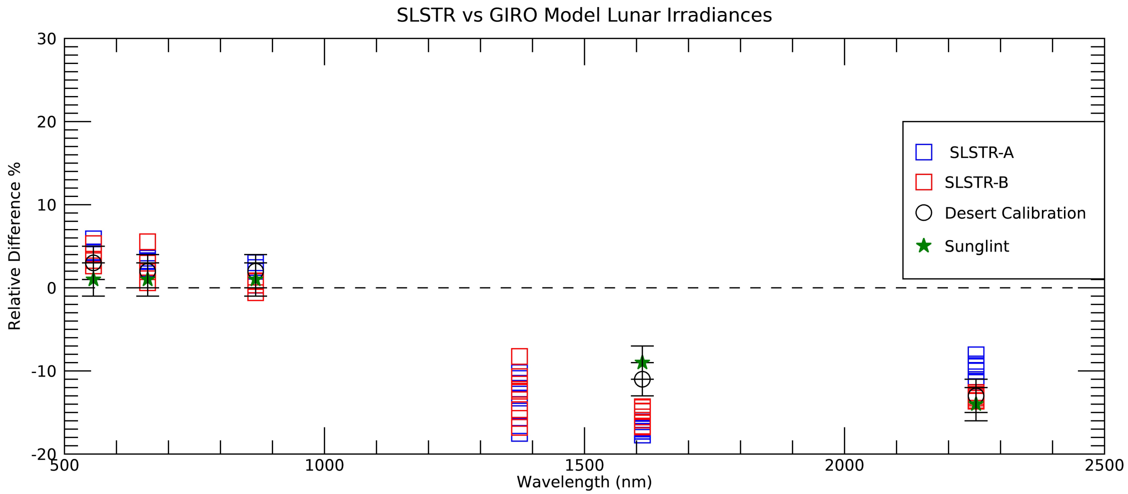
Both SLSTR-A and SLSTR-B are ~ high wrt. GIRO data.

Also, comparisons are high wrt. desert calibration and sun-glint results.

Science Technology Facilities
RAL Space

SLSTR vs GIRO





Across-track spacing assumes that detectors are viewing 100% of 40μs pixel interval.

However, integration time for SWIR is 35μs.

If we multiply across-track interval by 35/40 we now get much better agreement with vicarious calibration.

Is this a happy coincidence?

Note S1-S3 are not integrated but use a filter to match sampling of SWIR channels.

RAL Space